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THE PIONEER PROJECTS – ECONOMICAL EXPLORATION OF THE SOLAR SYSTEM

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INTRODUCTION

For the past thirteen years, the Ames Research Center of the National Aeronautics and Space Administration has been assigned project management responsibility for the interplanetary Pioneer missions. The objective of these missions is to perform scientific explorations of the interplanetary medium and extraterrestrial planetary environments at modest cost. During the planning and implementation phases of these missions, technical and resource management and control practices have been employed by the Pioneer Project Office to assure mission success at minimum cost.

PIONEER MISSIONS

The current Pioneer Program consists of three active projects: Pioneer A-E, Pioneer F/G, and Pioneer Venus, as indicated in Figure 1. The spacecraft and their launch dates for these missions are depicted in Figure 2 to

PROJECT	PIONEER A–E				PIONEER F/G		PIONEER VENUS	
PROJECT APPROVAL DATE	11/9/62				2/8/69		10/16/74	
MISSION	6	7	8	9	10	11	ORBITER	MULTIPROBE
LAUNCH DATE	12/16/65	8/17/66	12/13/67	11/8/68	3/3/72	4/6/73	5/78	8/78
ARRIVAL DATE JUPITER SATURN VENUS	N/A				12/4/73	12/3/74 9/79	12/78	12/78
MISSION OBJECTIVE	ELECTROMAGNETIC AND PLASMA PROPERTIES OF INTERPLANETARY MEDIUM BETWEEN 0.75 AND 1.20 A.U.				INTERPLANETARY MEDIUM AND JUPITER ENVIRONMENT	INTERPLANETARY MEDIUM AND ENVIRONMENTS OF JUPITER AND SATURN	VENUS ENVIRONMENT AT ALTITUDES ABOVE 150 KM	VENUS ENVIRONMENT TO SURFACE WITH BUS AND 4 PROBES
NUMBER OF EXPERIMENTS	7	7	8	8	13	14	18	14
NUMBER OF SCIENTIFIC INSTRUMENTS	6	6	7	7	11	12	12	12
SPACECRAFT WEIGHT, KG (LBS)	63(138)	63(138)	66(144)	67(148)	257(566)	259(571)	891(1965)	576(1270)
LAUNCH VEHICLE	THRUST AUGMENTED IMPROVED DELTA				ATLAS CENTAUR WITH TE-364-4 UPPER STAGE		ATLAS CENTAUR	
COST*, $M	64.3				94.7		168.8	

*PRIMARY MISSIONS EXCLUSIVE OF LAUNCH VEHICLE COST

Figure 1. Pioneer Projects.

approximately the same scale. In addition, a Pioneer Jupiter Orbiter/Probe mission is under study for the 1980 or 1981 launch opportunity.

The Pioneer A-E Project was approved in 1962 to explore the interplanetary medium within a region from 0.75 to 1.20 A.U. from the sun. Characteristics of the magnetic field, plasma, cosmic rays, high energy particles, electron density, electric fields, and cosmic dust have been investigated with four spacecraft, Pioneers 6-9, which were launched during the period of December 1965 through November 1968 to cover the period from near minimum

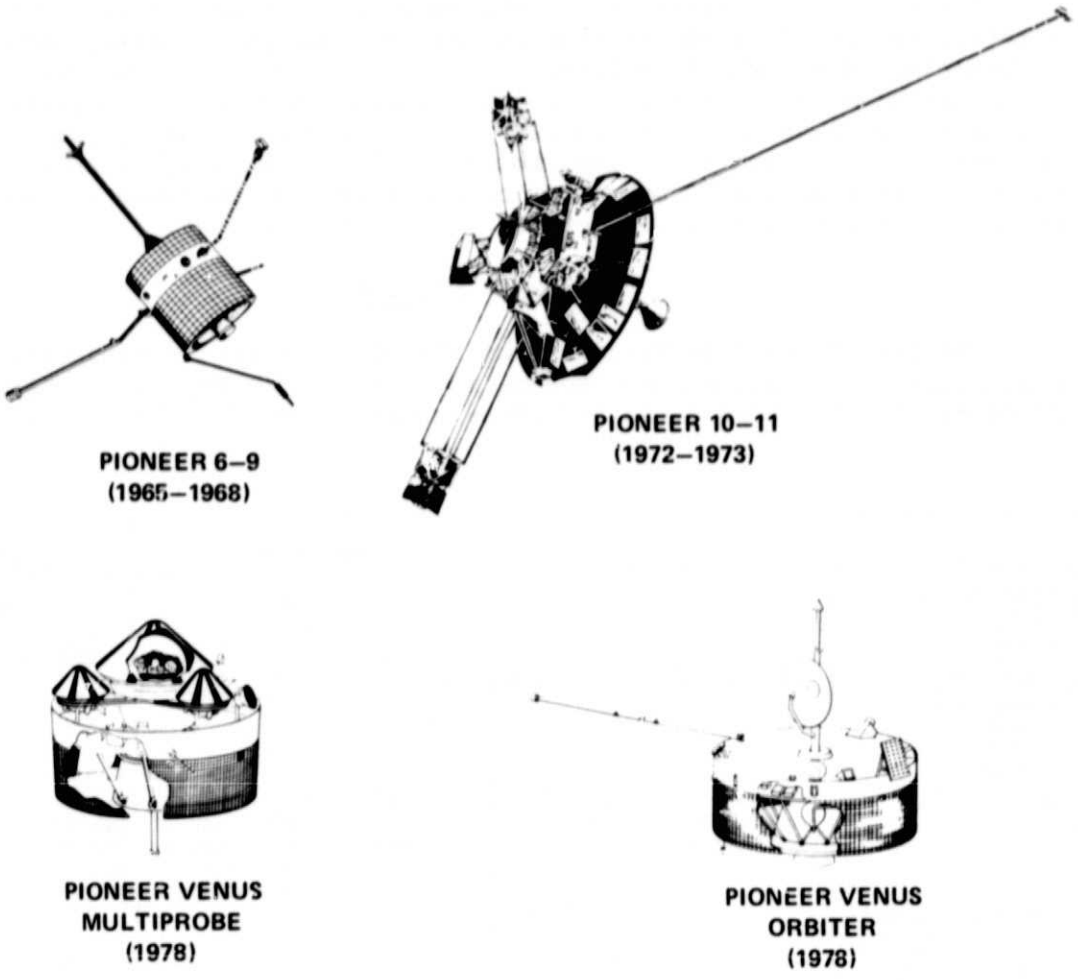

Figure 2. Pioneer Spacecraft.

to near maximum solar activity. The data from these spacecraft are providing a better understanding of the mechanisms associated with the spatial propagation of solar disturbances and the relationship between solar and terrestrial fields. Near real-time data are provided in a Pioneer Weather Report to the U.S. Space Distribution Forecast Centers. Since the primary mission objectives of the Pioneer A-E Project have been successfully achieved, the mission objectives have been changed to the performance of synoptic studies of the previously mentioned interplanetary phenomena and the study of these phenomena during special events such as solar occultation, solar events, and radial/spiral alignments with other Pioneer and Helios spacecraft. A description of the Pioneer 6-9 missions and some of the scientific results are presented in Refs. 2, 3 (Nunamaker et al., 1968; Reiff, 1969).

The Pioneer F/G Project was approved in 1969 to conduct exploratory investigations of (1) the interplanetary medium beyond the orbit of Mars, (2) the nature of the Asteroid Belt, and (3) the environmental and atmospheric characteristics of the planet Jupiter. The first scientific objective

is concerned with the characteristics of the magnetic fields, solar winds, and solar and galactic cosmic rays; the interaction of these particle and field phenomena; the location of the heliospheric boundary; and the properties of interplanetary dust. The second objective involves the measurement of the size, mass, flux, velocity, and orbital characteristics of the small particulate matter within the Asteroid Belt. An equally important engineering objective was to determine the extent of any hazards to future spacecraft caused by matter within the Asteroid Belt. The third scientific objective was to make in situ measurements of the characteristics of the magnetic field and radiation belt, perform measurements of the heat balance of the planet, search for helium in the planet atmosphere, make photometric and polarization measurements of the light reflected from the planet, perform close-up, spin-scan imaging of the planet's surface, make measurements of the ionosphere of Jupiter and Io, and determine the mass of Jupiter and the Galilean satellites. Pioneer 10 was launched in March 1972 and encountered Jupiter in December 1973 to within 2 Jupiter radii of the planet surface in a near-equatorial passage, successfully achieving the second and third mission objectives. Meeting the first objective will not be completed until about 1977 when the spacecraft nears the orbit of Uranus and the signal from the spacecraft becomes too weak to be detected by the ground receivers. Pioneer 11 was launched in April 1973 and encountered Jupiter in December 1974 to within approximately 0.6 Jupiter radii of the surface at a higher latitude than Pioneer 10 and in a direction opposite to the rotation of the planet and the trajectory of Pioneer 10. This passage provided a broad longitudinal survey of the intense radiation belt in close proximity to the planet and also the opportunity for performing imaging polarimetry and infrared surveys of both the south and north polar regions. Pioneer 11 has been targeted to an encounter of Saturn in September 1979. Between Jupiter and Saturn, the spacecraft will return to within 3.5 A.U. of the sun on a trajectory which rises to 15° above the ecliptic plane, and will pass through the northern ecliptic fringes of the Asteroid Belt. Pioneer 11 has successfully achieved the second and third mission objectives. The first objective will not be completed until about 1980 when the electrical power from the Radioisotope Thermoelectric Generators become less than that required to operate the spacecraft. A description of the Pioneer 10 and 11 missions and some of the scientific results are presented in Ref. 1 by Hall (1974).

The Pioneer Venus Project was approved in 1974 to conduct scientific investigations of the planet Venus and its environment. Two missions are planned to be launched during the 1978 opportunity: an Orbiter mission in May, and a Multiprobe mission in August. The scientific objectives for the Orbiter mission are:

(1) In situ measurements of the detailed structure of the upper atmosphere and ionosphere

(2) Investigation of the interaction of the solar wind with the Venus ionosphere and with the small magnetic field in the vicinity of the planet

(3) Determination of the characteristics of the atmosphere and surface of Venus on a planetary scale by use of remote-sensing experiments

(4) Determination of the planet's gravitational field harmonics from perturbations of the spacecraft's orbit about Venus

The scientific objectives for the Multiprobe Mission are:

(1) Exploration of the nature and composition of the clouds

(2) Measurements of the composition and structure of the atmosphere from the surface to high altitudes

(3) Determination of the general circulation pattern of the atmosphere

The flight spacecraft system for both missions consists of a basic bus with mission-peculiar systems to meet the individual objectives of each mission. The missions have similar launch and interplanetary phases, but have unique planetary encounter phases.

The Pioneer Venus Orbiter Mission is designed to establish a scientific satellite in elliptical orbit around Venus. The spacecraft will carry a scientific instrument payload which will perform in situ and remote-sensing measurements of the planet and its surrounding medium. The Orbiter spacecraft is to remain in Venus orbit and be fully operational for a period of at least 243 Earth days.

The spacecraft for the Multiprobe Mission consists of a bus, a single large entry probe, and three identical small entry probes, each carrying appropriate scientific instruments. The probes will make in situ measurements during their descent through the atmosphere to the planet's surface and will be targeted for dispersed locations on the planet. The bus, which is the carrier and delivery system for the probes, will be targeted for shallow entry after the probes have been released and will provide a brief opportunity for upper atmosphere measurements before its destruction.

The Pioneer Jupiter Orbiter/Probe mission is being planned to perform a comprehensive scientific investigation of the planet Jupiter and its environment using a spin-stabilized Pioneer-class spacecraft. The proposed mission includes both an orbiting bus and an atmospheric entry probe. The scientific objectives for the Orbiter Mission are to determine:

(1) The interaction of the solar wind with the Jovian magnetosphere on at least three of the four sides of the planet (dusk, dawn, and midnight) during a three-year period (minimum) of orbit manipulation (approximately 40 orbits) using the Galilean satellites to accomplish changes in the period and eccentricity of the orbit

(2) The number of trapped particles as a function of radius and time for an extended period by use of the full range of satellite orbit adjustment capabilities

(3) The direct imaging of and the occultation by as many of the inner, equatorially aligned satellites as possible during the active life of the orbiter

(4) The extension of all Pioneer 10/11 experiments to obtain time-dependent relationships of meteorological and radiation phenomena of the planet

(5) The impact of satellite "sweeping" on the Jupiter magnetospheric and high-energy particle structure

The scientific objectives for the Probe Mission are to determine:

(1) The composition and structure of the atmosphere as a function of height to a pressure of at least 10 atmospheres

(2) The nature and composition of the clouds

(3) The net energy balance between incoming solar radiation and planetary emission as a function of atmospheric state

(4) The trapped-particle count during descent through the Jovian magnetosphere

PROJECT MANAGEMENT STRUCTURE

The effective technical and administrative management of a major space effort such as the Pioneer Program requires a highly integrated team of individuals with clearly established lines of authority, responsibility, and communication.

The organizational structure for a typical Pioneer Project is shown in Figure 3. A Project Approval Document approved by the NASA Associate Administrator assigns Program, Project, and Systems responsibilities to various centers within NASA. The overall management responsibility for the Pioneer Projects has been assigned to the Ames Research Center at Moffett Field, California, which in turn has established a Pioneer Project Office, headed by a Pioneer Project Manager, to discharge this responsibility. In addition, the Ames Research Center has been assigned the responsibility for the Spacecraft, Experiment (including scientific instruments), and Mission Operations Systems, as indicated in Figure 3. Tracking and data acquisition is the responsibility of the Jet Propulsion Laboratory which operates the NASA Deep Space Network. The launch vehicles are provided by the Lewis Research Center, and the launch operations are the responsibility of the Kennedy Space Center located at the launch site. Letters of agreement between the Pioneer Project Office and these external organizations are cosigned by both parties early in the program and define their specific responsibilities.

The organizational structure and areas of responsibility within the Pioneer Project Office at Ames Research Center are indicated in Figure 4. With the exception of Project Support activities (shown as a broken line), all of these elements are staffed with personnel functionally assigned to the Pioneer Project Office on a full-time basis. In addition, the Pioneer Contracts and the Reliability and Quality Assurance Offices are located in the same building as the Project Office. Science support is provided by the

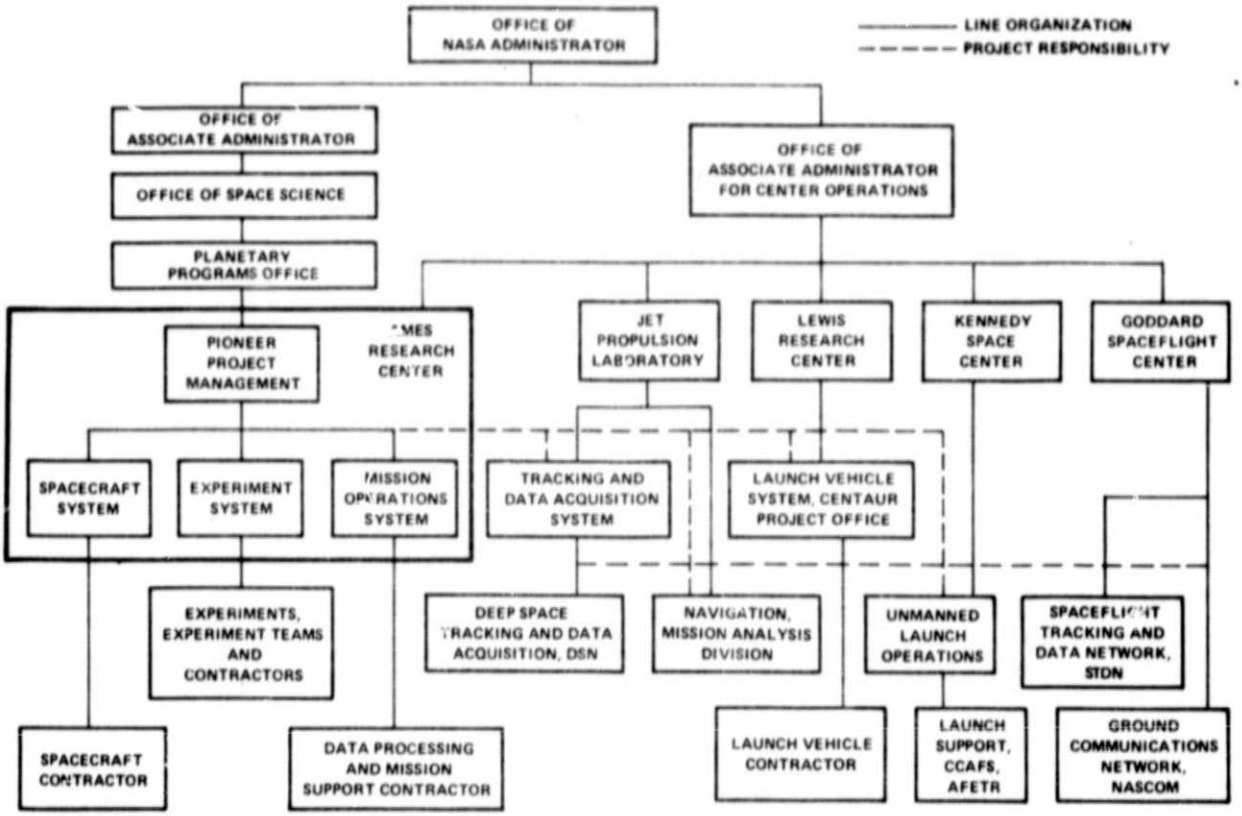

Figure 3. Pioneer Program Organization.

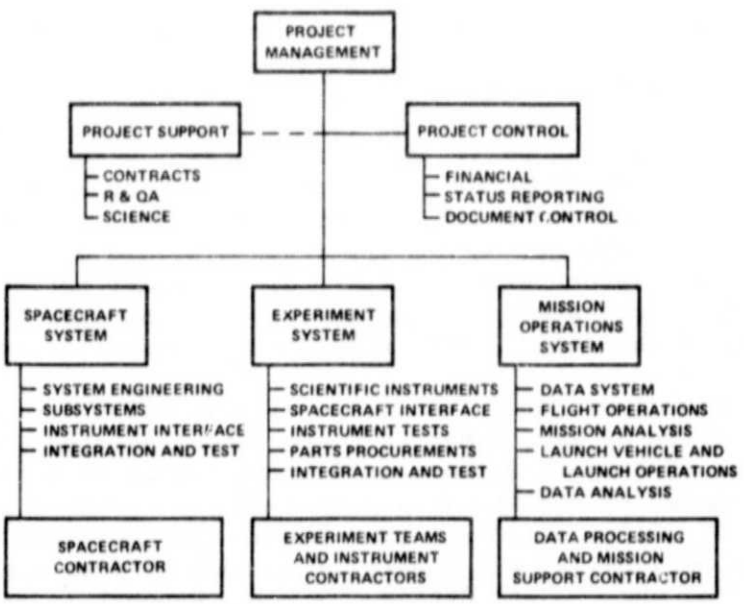

Figure 4. Pioneer Project Office.

Project Scientist on a part-time basis. This highly "Projectized" type of organization is a key factor in the success enjoyed to date by the Pioneer Project Office in meeting mission objectives on a timely basis with a minimum expenditure of resources.

A Project Control Office, functioning as a staff organization to the Project Manager, has the responsibility for maintaining control over the financial planning and transactions of the project, coordination and control of technical specifications and other documentation prepared by the Project Office, status reporting within the Project and to NASA Headquarters, and the performance of all project-wide administrative functions.

The three line organizations shown in Figure 4 are responsible for the spacecraft, experiments, and mission operations. The spacecraft group is responsible for the planning, preparation of technical specifications, and management of the prime contractor for the spacecraft systems. A staff of engineers having appropriate specialties is assigned to this activity to exercise surveillance over the contractor in the design and development of each subsystem and in the integration and test of the all-up spacecraft systems. The experiments group is responsible for the planning, preparation of technical specifications, and management of the scientific instrument contractors. The engineers assigned to this group closely monitor and coordinate the activities of each of these contractors during the design and development of each instrument to assure delivery of flight-qualified hardware on a schedule compatible with the spacecraft need dates. In addition this group is responsible for coordinating interface activities with other systems, managing an electronics parts procurement and screening system, and overseeing functional tests of the instruments during integration on the spacecraft. The mission operations group is responsible for the planning and preparation of requirements for the on-line, off-line data processing system, flight operations, navigation and mission analysis, coordination of launch vehicle and launch operations activities, and the monitoring of the scientific data analysis contracts. As part of this effort, the mission operations group is responsible for managing the on-site support services contractor that prepares software for the data system and provides flight operations support.

In addition to their responsibilities for assuring acceptable technical performance of their systems, the Pioneer Project line organizations perform a key role in the reduction and control of project costs. Because of their intimate day-to-day familiarity with the design, development, and status of each subsystem, instrument, or other activity, members of these groups are in a unique position to recommend less costly ways of meeting the system requirements, to identify contractor effort or tasks in excess of that required to meet mission objectives, and to assess contractor technical performance underlying variances of actual from planned costs. These groups also provide valuable inputs in the evaluation of technical progress within planned costs.

In addition to the organizational structure indicated in Figures 3 and 4, special boards and working groups are organized to assure that the Pioneer project requirements for DSN tracking and data acquisition support, launch vehicle performance and interface, and launch operations support are compatible with the needs of other space programs and with the plans of the supporting

organizations having management responsibility for specific aspects of the Pioneer Project.

PROJECT MANAGEMENT PRIOR TO HARDWARE PHASE

The preponderance of costs associated with the Pioneer missions is required to procure services and hardware from commercial firms, educational institutions, and government organizations. Formal contracts are entered into by Ames Research Center with commercial and educational organizations for major procurements ($10,000 and above), and letters of agreement are signed by the Pioneer Project Office with government organizations for such procurements. The structure and content of the letters of agreement are the same as for contracts to provide uniformity among the project procurements. Because of the predominance of the contracts and letters of agreement (hereinafter referred to as contracts), the primary emphasis of the Pioneer Project Office is directed toward the technical and financial management of these contracts, the objective of which is to obtain a product at minimum cost that meets the mission requirements and has a high probability of successful performance.

One of the most effective means for minimizing the cost of a development contract is to keep the changes during the hardware phase to as low a level as possible. In an effort to achieve this goal, the Pioneer flight hardware contracts are preceded by relatively short-term, low-cost feasibility and definition study contracts for both the spacecraft and for the undeveloped scientific instruments to establish realistic mission requirements. Typically, two spacecraft contractors are selected to perform parallel studies of the mission and of the spaceflight system proposed to accomplish that mission. During this study phase, spacecraft instrument interface problem areas are identified and a preliminary interface is established. Based on the results of these studies, requirements specifications are prepared by the Pioneer Project Office for incorporation in the Requests for Proposals issued to the potential spacecraft contractors and to the instrument contractors for the design and development of flight hardware.

In order to achieve the goal of minimum changes to the hardware contracts, it is considered essential to establish a mutual understanding between the Pioneer Project Office and the contractor of the mission requirements. Accordingly, a detailed evaluation of the cost and technical proposals submitted by the proposers is performed by the Project Office. After contractor selection, a comprehensive review of each proposal is performed jointly with the contractor to assure that there are no areas of misinterpretation and that all known problem areas are identified. At the conclusion of this review, the requirement specifications prepared by the Pioneer Project Office are firmed up on the basis of the joint proposal review. The resulting specifications are then reviewed in detail with the contractor to assure that the requirements are unambiguous and that there is complete agreement on their content and implications. The final step in establishing mutual understanding of requirements relates to the planning documents submitted by the contractor to the Pioneer Project Office subsequent to the detailed specification review. The Project Office reviews and evaluates these documents to

assess the contractor's understanding of the requirements, and negotiates any changes necessary to reflect mutual agreements of the specifications. Following detailed evaluation of any cost or technical changes proposed by the contractor as a result of this review process, the hardware contract is negotiated and definitized. Cost-reimbursement-type contracts are written with the spacecraft and scientific experiment contractors. A multiple-incentive fee structure, including cost, schedule, management, and spacecraft performance incentives, is typically incorporated in the spacecraft contract as a means for stimulating the contractor to meet the mission requirements at minimum cost.

PROJECT MANAGEMENT AND COST CONTROL DURING HARDWARE PHASE

The achievement of mission objectives at minimum cost requires a high degree of visibility of the performance of all elements of the project on a continuing basis. Visibility of the Project performance is achieved by various special-purpose meetings and reviews. Interface-coordination meetings are held at frequent intervals to review the status and resolve problem areas relative to the following interfaces with the Pioneer missions:

(1) Mission - DSN

(2) Mission - Launch Operations

(3) Mission - Launch Vehicle - Spacecraft

(4) Mission - Instruments - Spacecraft

To maintain control over the establishment of these interfaces, all interface meetings are participated in by at least one member of the Pioneer Project Office. Any exchange of information or assignment of action between external parties is implemented only with the knowledge and concurrence of the Pioneer Project Office. Also, each interface is controlled by a specification or a letter of agreement prepared by the Pioneer Project Office.

Weekly staff meetings are held by the Pioneer Project Manager with the managers or representatives of the Pioneer organizational segments — Spacecraft, Experiments, Mission Operations, Project Control, Contracts, and Science — to review the current status and outstanding problem areas and to exchange information of mutual concern.

Periodic reviews of the Pioneer Projects are held by the Director of Ames Research Center with the Pioneer Project Manager. A project-wide review is held by NASA Headquarters on a quarterly basis to review the progress and plans of all elements of the project. Science steering groups, where applicable, meet as needed to provide guidance on the scientific requirements for the flight instruments. A pre-ship review is held at the spacecraft contractor's facility at the completion of the flight acceptance test program for each spacecraft to be shipped to the launch site. The purpose of this review is to verify that the spacecraft and its complement of scientific instruments function successfully under simulated launch and mission environments. A

pre-launch review is held prior to lift-off at the launch site for each spacecraft launch vehicle combination. The purpose of this review is to verify that all spacecraft, launch vehicle, and ground support systems are in a state of readiness for launch.

Visibility of the spacecraft contractor performance is achieved from design reviews, contractually required documentation and reports, periodic status reviews, personal contact, and change proposals. Conceptual, subsystem and final design reviews are actively participated in by members of the Pioneer Project technical staff to assure that the proposed design is consistent with the performance specification requirements and that low-cost approaches have been adequately considered in the design. Contractually required documentation, prepared by the contractor, is submitted to the Pioneer Project Office to describe the contractor's plans for implementing the spacecraft design and development; present specifications for parts, materials, equipment, interfaces and environmental tests; report on financial status, technical progress, tests, nonconformances, and failure reviews; and to provide information on other aspects of the contract. Each of these documents and its revisions are submitted to the Pioneer Project Office for either approval, review, or information. Approval signifies that work shall not be implemented until written approval is obtained from the Pioneer Project Office. Review signifies that the contractor may proceed if written notification of disapproval is not received within a specified action period. Information refers to documents submitted for the purpose of reporting on program status or progress. To minimize documentation costs, the contractor is requested to submit wherever possible documentation used by the contractor's organization in the normal conduct of business, rather than rewrite a document in a special format.

An office staffed by Pioneer Project Office personnel is established at the spacecraft contractor's facility to provide daily monitoring of the contractor's activities. The in-plant representative also participates regularly in the weekly status reviews conducted by the contractor. On the day following each of these meetings, he communicates to the Pioneer Project Office details of the discussions on key issues and problem areas presented at these reviews. In addition, copies of the documentation prepared for these reviews are forwarded to the Pioneer Project Office for information. This documentation contains a summary of the current manpower, cost, schedule, and problem areas for each of the subprograms and subsystems.

Regular management meetings between the Pioneer Project Office and the contractor are held at the contractor's facility on a monthly basis to review and resolve any open issues of a management nature and to obtain visibility of the basis for the contractor's cost and technical performance.

A monthly technical report is submitted to the Pioneer Project Office by the contractor detailing his technical progress and accomplishments during the reporting period. Contract change proposals provide an additional avenue for attaining visibility of the contractor's technical and cost performance.

Visibility of the instrument contractor's performance is achieved from design reviews, contractually required documentation and reports, personal

contacts, and change proposals. Instrument design reviews are actively participated in by cognizant members of the Pioneer Project technical staff. Documents are submitted by the instrument contractors to provide information and reporting on development plans, financial status, and technical progress. Periodic visits by cognizant engineers and bi-weekly telephone status reports provide first-hand information on the status, performance, and current problem areas.

MANAGEMENT IMPLEMENTATION

Implementation of the Pioneer Project management process is accomplished with various management tools. Interface coordination meetings, participated in by Pioneer Project personnel, are held on an as-needed basis to review the status, identify problem areas, and assign actions for their resolution. Special purpose boards and working groups are participated in by the Pioneer Project Office to ensure compatibility of Pioneer mission requirements with the capability of external organizations supporting Pioneer launch and flight operations, including ground data systems, telecommunications, mission operations, DSN support, launch vehicle performance and trajectory, spacecraft/launch vehicle hardware interface, and launch operations. A Science Steering Group is being utilized on the Pioneer Venus Project to provide advice on science-related matters and to insure that the scientific objectives of the Orbiter and Multiprobe missions are achievable with the design proposed for the spacecraft system. This group consults with the Project Office and Principal Investigators to insure that the best mission science can be obtained for the lowest cost, utilizing integrated results from the two missions. Centralized control of mission requirements and contract changes, preparation and revision of performance specifications, and close monitoring of all major contracts are used by the Pioneer Project Office as effective tools in successfully managing project activities.

A status monitoring system has been initiated by the Pioneer Project Office to maintain continuous surveillance over the progress, costs, and problem areas associated with each spacecraft subsystem or subprogram and each scientific instrument. The cognizant engineer for each of the spacecraft elements prepares a weekly assessment of the contractor's performance based on the reports presented at the contractor's weekly status review and on direct contacts with contractor personnel. The cognizant engineer for each instrument prepares a bi-weekly evaluation of the contractor's performance based on accomplishment information received by telephone from the contractor's representative and on financial management reports submitted by the contractor. Cost performance, manpower utilization, and detailed milestone charts are maintained by the cognizant engineers to assist in these evaluations.

A computerized financial control program has been implemented within the Pioneer Project Office to provide a centralized mechanism for listing the current expenditures and the time-phased estimated cost to complete for each of the project cost accounts. This program functions as the primary tool in the overall assessment of the current financial status of the project, the control of expenditures, and the establishment of budgets.

A monthly project management report, which is prepared by the Pioneer Project Office for submittal to NASA Headquarters, summarizes the accomplishments, problem areas and financial status of each project in the development phase. These reports provide the information necessary for program management at the NASA Headquarters level.

MANAGEMENT-CONTROL METHODS

The achievement of minimum cost requires the application of selected management controls which encourage the contractor to adopt low-cost approaches in the design and development of space hardware within acceptable risk levels. For large cost-reimbursement type contracts, such as the Pioneer spacecraft contracts, a properly balanced multiple-incentive fee structure is incorporated to motivate the contractor toward this end. Cost, schedule, management, and spacecraft performance are typical incentives included in the fee provisions. A portion or all of the total fee is an award fee unilaterally established by a NASA Award Fee Determination Official based on the recommendations of an Award Fee Evaluation Board. The award fee is determined on an incremental basis for several periods of performance corresponding to various stages of effort. A copy of the Award Fee Evaluation Board report is submitted to the contractor after completion of each period of performance to inform the contractor of any shortcomings or deficiencies during that period, with the intent that this assessment will lead to improved performance during subsequent periods.

Contractual and technical direction of the contractor is employed by the Pioneer Project Office, when necessary, to redirect the contractor's effort or to change the specification requirements. Management control of the contractor's effort is also exerted by the Pioneer Project Office through the approval of certain contractually required documents such as the Development Plan, Reliability and Quality Assurance Plan, Test Program Plan, Deviations and Waivers, and the approval of electronic parts procurement.

Management control of the contractor by the Pioneer Project Office is augmented by contract administration support of Department of Defense in-plant representatives.

LOW-COST APPROACH

The major objective of the Pioneer Program is to accomplish the scientific objectives at the least possible overall program cost. Accordingly, all organizations participating in a Pioneer Project are made aware of the importance of minimizing costs. During the initial definition study phase, potential contractors are requested to place major emphasis on achieving minimum cost and to propose low-cost approaches consistent with the mission requirements. These contractors are instructed to use the following cost-saving approaches:

(1) Use existing and proven designs wherever feasible

(2) Use standardized hardware to the maximum extent

(3) Increase design margins to minimize testing

(4) Minimize requirements for design analyses

To facilitate application of these approaches to the Pioneer Venus missions, the Atlas/Centaur launch vehicle was selected for both the Multiprobe and Orbiter missions to minimize the constraints of hardware weight and volume. The major cost-saving feature incorporated in the Pioneer Venus Project is the use of the flight spacecraft for system qualification tests, thereby eliminating the need for a separate prototype spacecraft involving a complete set of flight quality hardware and the associated unit- and system-level testing. The risk associated with this approach is the possible degradation in reliability due to exposure of the spacecraft to qualification-level environments. This risk is minimized by reducing the test levels to values approximately midway between acceptance and qualification levels. Another significant low-cost approach employed on the Pioneer Venus spacecraft contract is the common unit and structural designs for the orbiter, bus, and probes. Other cost-saving features applied to Pioneer Projects are as follows:

(1) Use of existing and proven unit designs

(2) Deletion of unit life tests in those cases where adequate test data exist to justify this approach

(3) Use of qualification units for spares

(4) Common set of subsystem test equipment for development and flight hardware testing

(5) Combined structural and thermal development test models

(6) Deletion of requirement for unit level design specifications

(7) Deletion of requirement for formal unit-level flight hardware test reports

(8) Use of most economical test facilities to meet mission requirements

(9) Maximum use of existing contractor documents

In addition, a number of task-unique cost-saving approaches are incorporated during the course of the development of the spacecraft and scientific instruments for the Pioneer missions.

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